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3

Airfield vulnerability trials at West Freugh, October 1969 and Swynnerton, Staffordshire, December 1969

5 December 1970

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Summary

An account is given of trials at RAE, West Freugh, Wigtownshire, and on the site of the former ROF at Swynnerton, Staffordshire, in which a variety of shaped charges were fired against 12in. thick concrete pads. Careful assessment of the resulting damage leads to the conclusion that for a charge of this type to be successful against runways, it would have to be at least 5 inches in diameter. The relationship between shaped charge characteristics and concrete damage is given. The performance of some other types of charge in the anti-runway role is also described and discussed.

Approved for issue:

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1. INTRODUCTION

Reference (1) gives an account of a trial at Waterbeach in Cambridgeshire, in which it was concluded that the BL755 bomblet type of shaped charge was unlikely to be effective in the anti-runway role. Subsequently D Air Arm requested that further trials be done on a concrete pad which was available at RAE, West Freugh. It was decided after discussions with WE1, RAE, Farnborough that the performance of a wide range of shaped charges including BL755 should be assessed in various attitudes to the target. In addition it was agreed that a preliminary study should be made of Miznzy/Schardin type charges and plastic explosive charges in contact with the concrete; these latter trials were carried out at both West Freugh and Swynnerton.

All the charges fired in the course of this work were experimental types, assembled in cardboard tubes and not optimised for explosive weight but used in the interests of time and economy. Whilst their shaped charge performance is identical to that from a similar size metal round, the absence of the case and the reduction in the explosive filling must reduce the debris. In view of this, actual BL 755 warheads were fired against concrete and their performance established and the fragmentation assessed.

2. EXPERIMENTAL

The experimental shaped charges were constructed by fitting copper liners in cardboard tubes, filling with RDX/TNT 60/40, and then attaching the wooden stands constructed to provide the appropriate stand-off and angle of attack. A typical charge placed on the concrete pad at West Freugh is shown in Fig. 1a.

A series of conical shaped charges was fired with copper liners of angle 40°, 60° and 80°, and diameter ranging from $2\frac{1}{4}$in. (BL755) to 7in. as used in the Rapid Cratering Device. A number of 4in. diameter Miznay/Schardin charges were also fired normal to the concrete target; these were fitted with either steel or polycarbonate missile plates.

The maximum dimensions of the craters produced were measured and recorded. The general characteristics are similar to those shown in Fig. 7 of reference 1, in which the signature of the charge on the concrete had three main characteristics viz., main crater, main borehole which was frequently blocked, and a secondary crater (Fig. 1b). No attempt was made to clear the craters in view of another objective of the work which was to assess the effort required to repair the airfield surface. It is emphasised that only maximum dimensions are reproduced in the results, and any conclusions on the "obstacle value" can only be tentative.

3. RESULTS

3.1 BL755 type shaped charges

A total of fortyeight BL755 type shaped charges was fired in various attitudes. To establish the basic performance of the charge the first two were fired perpendicularly at concrete. The results obtained are recorded in Table 1.

A pattern of ten charges was located at 18ft centres and fired against concrete at an angle of 20° and a stand-off of 9in. The results obtained are tabulated in Table 2 and are very similar to those recorded at Waterbeach (1). A further pattern of nine shaped charges, located at 3ft centres as shown in Fig. 2a was fired simultaneously to establish whether such an arrangement would lead to additional damage due to shockwave interaction between craters. The results obtained are recorded in Table 3 and a photograph of the resultant cratering is reproduced in Fig. 2b. It can be seen that there was little extra damage over what would have been predicted from single shot firings.

The mean BL755 performance at an attack angle of 20° and stand-off of 2D (where D is the diameter of the cone) has been calculated from Tables 2 and 3. Values of depth, length and width were respectively 3.5, 18.1 and 14.5in., which are very similar to those obtained at Waterbeach (1).

Following this, a number of charges were fired at stand-offs ranging from 0 to 4D. The results obtained are reproduced in Table 4 and the mean depth values plotted against stand-off in Fig. 3. It can be seen that there is little significant change in performance between 1 and 3D, and a stand-off of 2D can be considered satisfactory.

Whilst most of the cratering data obtained for this charge was determined with the charge at 20° to the target, its performance was also assessed at angles of 15° and 10° with the stand-off fixed at 2D. The results obtained are recorded in Table 5; the mean performance is illustrated in Fig. 4 together with the mean performance previously obtained at 20°. It can be seen that a 20° angle of attack is preferable to smaller angles. Earlier work (1) had shown that at angles greater than 20° the size of the crater became smaller. It is apparent therefore that an attack angle of 20° is optimum for the BL755 type shaped charge. It was found possible during the Swynnerton trial to fire one actual BL755 warhead at a stand-off of 2D and an attack angle of 20°. The resulting crater was some 46in. long, 7½in. wide and 1¾in. deep. A secondary crater come 4in. wide and 5in. long was apparent but its depth was so insignificant that it could only be classified as a scrape. It is clear from this result that the experimental charge is more effective than the actual BL755 warhead. The latter has a conical rather than cylindrical control contact, explosive having been removed in the region behind the open end of the cone. Although this smaller explosive charge causes no significant reduction in jet performance and fragment velocity, the general explosive effect on the concrete surface is less.

Another important feature of the BL755 charge is its fragmenting metal case and it has been suggested that the presence of these fragments on the runway might add to the time required for airfield repair. Five hundred typical fragments weighing about 49 gms recovered from the firing of an actual BL755 warhead in an arena of strawboard packs are illustrated in Fig.5. It is estimated that a total of about 2,800 such fragments are produced but it is unlikely that they would add to the obstacle value of the actual craters.

3.2 Digging Aid Shaped Charges

The shaped charges in the UK Trench Digging Aid are fitted with 80° angle, 2½in. diameter copper liners; twenty of these were used in the trials with experimental shaped charges (see section 2) and the effect of attack angles of 10°, 20° and 30° at a stand-off of 2D were then assessed. The results obtained are recorded in Table 6. It can be seen that the optimum of attack is between 15° and 20° and for comparative purposes the mean dimensions of the primary crater from different sized charges at 20° have been plotted in Fig.6.

3.3 The effect of charge diameter and cone angle

The effect of cone angles of 40°, 60° and 80° on shaped charge performance was assessed for 3, 4, 5, 6 and 7in. diameter shaped charges, fired at an attack angle of 20° and a stand-off of 2D. The results obtained are recorded in Tables 7-11, and from these, mean crater dimensions produced by the charges fitted with 80° cones have been calculated and plotted in Fig.6. A photograph of a typical crater produced by a 5in. diameter charge is reproduced in Fig. 7(a) and by a 7in. diameter charge in Fig. 7(b). It is considered that the former is the size of crater which might be effective in runway denial.

An attack angle of 20° was used throughout this part of the exercise as this is the most likely angle of attack for the BL755 warhead and had been used in the early work. It would have been desirable to determine the optimum angle of attack for all the charges, but this would have led to a prohibitive number of firings.

The results plotted in Fig. 6 show that for charges fitted with 80° cones all dimensions of the crater increase with charge diameter. The effect of cone angle is not so clear (Tables 7-11) although it does lead to changes in crater geometry. It is difficult to decide which is the most effective cone angle particularly as optimum crater geoemtry has not been specified. There are trends which indicate that a 40° cone produces the largest crater, ie, greatest volume, and a 60° cone the deepest crater, although other results can be selected favouring the 80° cone. However, as jet penetration itself is not a prerequisite, charges fitted with 80° cones would contain more explosive, and on this basis alone the use of a wide angle liner would seem sensible.

3.4 Three and 4in. diameter Miznay/Schardin Charges

A number of the Miznay/Schardin (M/S) charges of the type illustrated in Fig. 8 were fired perpendicularly at the target at various stand-offs. Two types of missile plates were used and it can be seen from the results in

Table 12 that the steel missile, particularly at the longer stand-offs gave the greater effect. These craters compare most favourably with those produced by a 4in. shaped charge at an attack angle of 20° (Table 8) particularly when it is appreciated that the 4in. charge is significantly heavier. Generally there was more rubble in the craters produced by M/S charges.

Following the West Freugh trial a number of 3in. diameter M/S charges were fired at various stand-offs and angles against a well matured, 6in. thick concrete surface at Swynnerton. The charge design is illustrated in Fig. 8 from which it can be seen that both polycarbonate and steel missile plates were used. The type E and H polycarbonate missiles differed slightly in spherical radius and were thicker than the steel missiles.

The results obtained for charges fitted with the steel missiles are recorded in Tables 13, 14 and 15. Although the number fired under one set of conditions is limited, it can be seen that the performance varies with one angle of attack and stand-off. The craters produced by charges 28 and 29 were probably the best but do not compare favourably with those produced by the equivalent shaped charges. (See Table 7). Clearly the shapes of the craters are different but those produced by the shaped charges are deeper and also produce larger secondary craters which must add a little to the time required for repairing the surface. Charge No. 30 fired normally at the target produced the largest crater.

The results obtained with the Miznay/Schardin charges fitted with polycarbonate missiles are reproduced in Tables 16 and 17. Generally all the craters produced were inferior to those produced by the steel missiles.

3.5 Plastic Explosive Charges

Previous experience with the squash head shell suggested that plastic explosive charges placed in intimate contact with the concrete surface might be effective for runway destruction. With this in mind a number of plastic explosive charges, ranging in diameter from 3 to $7\frac{1}{2}$in. and thickness from 1 to 6in. were fired at Swynnerton. One single $7\frac{1}{2}$in. diameter charge was fired at West Freugh. The results obtained are recorded in Table 18.

Generally the maximum diameter of the resulting basin-like crater was some three to four times the diameter of the charge. Comparison of the results on a constant diameter basis leads to the conclusion that the depth of the crater is dependent on charge thickness. The deepest crater was obtained with charge No. 51 which was the largest charge used on the exercise.

The performance of these plastic explosive charges in contact with the concrete target compares very favourably with that of the other types of charges studied. A useful comparison is that of performance of charges with equal explosive weight. In general the plastic explosive charge in contact with the target produced a larger (in terms of maximum dimensions) crater than either the shaped or M/S charge of equal or rather greater weight fired at its optimum stand-off and attack angles.

4. CONCLUSIONS

An account has been given of the attack of concrete surfaces with various types of explosive charges. Although the exercise was concerned primarily with the performance of shaped charges fired at various stand-offs and angles, the merits of Miznay/Schardin and plastic explosive "contact" charges were also assessed.

A range of shaped charges was fired and the results show that there is a direct correlation between the diameter of the charge used and the size of the crater produced. For the BL755 type charges stand-offs should be in the range 1 and 2D and the optimum attack angle is 20°. The resulting craters however are such that the BL755 charge cannot be considered to be effective in the anti-runway role; it appears that a shaped charge of at least 5in. diameter is necessary to produce an effective crater.

Miznay/Schardin (M/S) charges with liners of both polycarbonate and steel were assessed and the latter found to be the more effective. The craters produced at low angles of attack were smaller than those produced by shaped charges, but at high angles, ie approaching normal to the target, the M/S system is superior.

If contact between a plastic explosive charge and the target can be guaranteed before initiation, the resulting damage is greater than that produced by the other types of charges of equal weight.

Other work on cratering (2) leads to the suggestion that the efficient destruction of airfield pavements can be achieved only by the detonation of an explosive charge beneath the concrete surface.

5. ACKNOWLEDGMENTS

Acknowledgment is given to Mr H.B. Young (E1 Branch, Woolwich) who manufactured the charges for the trials. Thanks are also due to the Officer i/c RAE, West Freugh, for his assistance and ready cooperation.

6. REFERENCES

(1) Unpublished RARDE Memorandum

(2) Unpublished RARDE project report

TABLE 1

BL 755 Type shaped charges fired normal to the target at a stand-off of $4\frac{1}{2}$in.

Ref. No.	Target	BORE HOLE	
		Dia. in.	Depth in.
147	Concrete 12in. thick	2	21 (Blocked after
148		$2\frac{1}{2}$	(13

TABLE 2

Pattern of ten BL 755 type shaped charges at 18ft centres
Stand-Off 9 in. : Angle of attack 20°

Ref. No.	Primary Crater			Secondary Crater			Distance between crater centres in.
	l in.	w in.	d in.	l in.	w in.	d in.	
1	13	15	$2\frac{3}{4}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$1\frac{1}{2}$	$19\frac{1}{2}$
2	19	12	3	6	6	1	24
3	26	19	4	7	5	1	27
4	19	13	4	6	7	$1\frac{1}{2}$	22
5	$16\frac{1}{2}$	$13\frac{1}{2}$	3	5	$5\frac{1}{2}$	1	22
6	18	13	3	$6\frac{1}{2}$	$7\frac{1}{2}$	1	24
7	21	19	$3\frac{1}{2}$	5	5	$1\frac{1}{2}$	24
8	23	23	3	6	4	$1\frac{1}{2}$	22
9	27	26	5	5	7	$1\frac{1}{2}$	28
10	22	20	4	6	$4\frac{1}{2}$	$1\frac{1}{2}$	26

TABLE 3

Pattern of Nine BL 755 type shaped charges at 3ft centres
Stand-off 9in. : Angle of Attack 20°

Ref. No.	Primary Crater			Secondary Crater			Distance between crater centres in.
	l in.	w in.	d in.	l in.	w in.	d in.	
11	16	11	3½	5½	6	1	21
12	13½	8	3	4½	5	1	20
13	17	17	3	5	5	1	21
14	17	12	3½	4½	5	1	21
15	20	13	3½	5	5	1	24
16	15	11	4	4	4	1	20
17	13	10	3	4	5	1	19
18	17	13	4	5	7	1	21

TABLE 4

Effect of Stand-off on BL 755 type Shaped Charges fired at 18ft centres

Angle of Attack 20°

Ref. No.	Stand-off Charge Dia.	Primary Crater l in.	Primary Crater w in.	Primary Crater d in.	Secondary Crater l in.	Secondary Crater w in.	Secondary Crater d in.	Distance between centres in.
25	0	24	12	4				$10\frac{1}{2}$
26	0	28	20	4				14
27	0	20	10	$2\frac{1}{2}$				$10\frac{1}{2}$
28	0	23	19	$2\frac{1}{2}$				12
29	0	21	16	4				$11\frac{1}{2}$
20	1	23	22	5	10	9	1	22
21	1	21	12	$3\frac{1}{2}$	5	6	1	20
22	1	18	13	4	8	6	1	20
23	1	14	14	$3\frac{1}{2}$	$6\frac{1}{2}$	$5\frac{1}{2}$	1	18
24	1	13	11	2	$8\frac{1}{2}$	$7\frac{1}{2}$	$1\frac{1}{2}$	17
30	3	17	12	$2\frac{1}{2}$				22
31	3	14	$9\frac{1}{2}$	$3\frac{1}{2}$				21
32	3	26	3ft	4	About 3	Hardly a crater, more of a scrape		28
33	3	28	24	5				24
34	3	22	24	4				27
35	4	15	10	3				
36	4	17	15	$2\frac{1}{2}$	No second crater			
37	4	17	12	3				
38	4	30	24	$4\frac{1}{2}$				
39	4	18	15	3				

TABLE 5

Effect of Attack Angle on BL 755 type shaped charges fired at 12ft centres : Stand-off 2 charge diameters

Ref. No.	Angle of Attack	Primary Crater			Secondary Crater			Distance between centres in.
		l in.	w in.	d in.	l in.	w in.	d	
45	10	21	8	1½	6	5½	1	32
46	10	17	6	1½	8	10	1¼	29
47	10	20	9	2	7	6	1¼	30
48	10	17	7	1½	7	6	1	31
49	10	17	6	1		Scrape		
40	15	16	15	3½	6½	6	1	22
41	15	15	13	3	7	4½	1	24
42	15	16	7	2	6½	7	1	22
43	15	14	13	3	6½	6½	1	21
44	15	29	20	3½	7	5	1	30

TABLE 6

Effect of angle of attack on Digging Aid type Shaped Charges
Charge diameter $2\frac{1}{2}$in. : Stand-off 2D : Explosive weight 19ozs

Ref. No.	Angle of Attack	Primary Crater			Secondary Crater			Distance between centres in.
		l in.	w in.	d in.	l in.	w in.	d in.	
60	10	24	15	$4\frac{1}{2}$	9	9	$1\frac{1}{2}$	27
61	10	26	17	$4\frac{1}{2}$	9	9	$1\frac{1}{2}$	33
62	10	20	18	4	9	9	1	28
63	10	19	16	4	9	9	1	21
64	10	18	8	3	9	10	$1\frac{1}{2}$	28
55	15	24	15	$4\frac{1}{2}$	8	7	$1\frac{1}{2}$	28
56	15	35	17	5	9	6	$1\frac{1}{2}$	34
57	15	16	13	4	8	8	$1\frac{1}{2}$	23
58	15	16	12	$3\frac{1}{2}$	10	9	$1\frac{1}{2}$	23
59	15	24	21	4	7	9	$1\frac{1}{2}$	27
50	20	25	18	5	5	5	1	29
51	20	25	18	$3\frac{1}{2}$	$6\frac{1}{2}$	6	1	22
52	20	29	22	$4\frac{1}{2}$	7	6	1[illegible]	30
53	20	19	19	$2\frac{1}{2}$	6	5	$1\frac{1}{4}$	21
54	20	15	15	$4\frac{1}{2}$	$6\frac{1}{2}$	6	$1\frac{1}{4}$	22
65	30	10	10	3	5	5	1	16
66	30	13	15	3	$6\frac{1}{2}$	6	1	18
67	30	11	10	$3\frac{1}{2}$	5	4	1	16
68	30	16	14	$3\frac{1}{2}$	5	5	1	18
69	30	13	12	$3\frac{1}{2}$	6	$5\frac{1}{2}$	1	17

TABLE 7

Effect of liner angle on shaped charge performance
Shaped charge diameter 3in. : Stand-off 2D : Attack angle 20°

Ref. No.	Liner Angle	Primary Crater			Secondary Crater			Distance between centres in.
		l in.	w in.	d in.	l in.	w in.	d in.	
70	40°	23	21	4½	9	11	1½	27
71	40°	23	11	3	9	9½	1½	30
72	40°	22	8	2	9½	9	1½	30
73	40°	24	16	4	8½	10	1½	33
74	40°	34	7	2½	8	10	1½	36
75	60°	17	12	3½	8½	9	1	24
76	60°	21	19	4	11	9	1½	24
77	60°	18	15	2½	8	7	1	22
*78	60°	19	16	4½				22
*79	60°	20	18	5				24
80	80°	18	16	6	9½	9	1½	24
81	80°	27	18	5	9	9	1½	30
82	80°	23	22	5½	9	10	2	28
83	80°	22	17	5½	8	8	1½	25
84	80°	30	20	5½	7	8	1	29

*Angle of attack 30°

	Charge Weight
40°	2lb 7oz
60°	2lb
80°	1lb 4oz

TABLE 8

Effect of liner angle on shaped charge performance
Shaped Charge Diameter 4in. : Stand-off 2D. Attack Angle 20°

Ref. No.	Liner Angle	Primary Crater			Secondary Crater			Distance between centres in.
		l in.	w in.	d in.	l in.	w in.	d in.	
85	40°	34	28	6	9	8	1	36
86	40°	30	25	6	9	8	1	35
87	40°	33	16	6½	11	8	1	36
88	40°	37	24	6	10	8	1	42
89	40°	46	37	6½	11	8	1	48
90	60°	28	26	7	10	8	1	32
91	60°	30	24	7	10	10	1	36
92	60°	32	29	7	10	8	1	38
93	60°	22	21	4½	11	9½	1½	32
94	60°	25	22	5½	10	6	1½	34
95	80°	24	24	5½	11	11	1	26
96	80°	29	27	6	11	8	1½	34
97	80°	22	16	5	9	9	1	28
98	80°	24	22	5½	10	10	1½	32
99	80°	22	22	5½	10	10	1	24

	Charge Weight
40°	6lb 2½oz
60°	4lb 13½oz
80°	4lb 5oz

TABLE 9

Effectof liner angle on shaped charge performance
Shaped Charge diameter 5in. : Angle of attack 20°
Stand-off 2D

Ref. No.	Liner Angle	Primary Crater			Secondary Crater			Distance between centres in.
		l in.	w in.	d in.	l in.	w in.	d in.	
100	40°	38	33	$8\frac{1}{2}$	10	8	splatter	39
101	40°	36	36+	8	11	8	splatter	38
*102	40°	32	28	7	14	9	1	36
*103	40°	34	27	7	13	12	1	30
104	40°	26	26	$7\frac{1}{2}$	11	8	splatter	36
105	60°	26	24	9	11	9	splatter	34
106	60°	24	20	7	10	10	1	34
107	60°	26	24	$9\frac{1}{2}$	11	$9\frac{1}{2}$	$1\frac{1}{2}$	36
108	60°	22	17	7	10	7	splatter	33
°109	60°	31	23	$7\frac{1}{2}$	7	6	splatter	42
°110	80°	24	18	8	10	9	1	36
°111	80°	24	18	7	10	10	1	36
°112	80°	36	20	$7\frac{1}{2}$	9	9	1	42
113	80°	29	24	$6\frac{1}{2}$	9	8	1	41
114	80°	25	21	$6\frac{1}{2}$	8	8	1	39

* Stand-off 1D   °Stand-off 3D

	Charge Weight
40°	11lb 11oz
60°	9lb 15oz
80°	8lb $4\frac{3}{4}$oz

TABLE 10

Effect of Liner Angle on Shaped Charge performance
Shaped Charge Diameter 6in : Attack angle 20°
Stand-off 2D

Ref. No.	Liner Angle	Primary Crater l in.	Primary Crater w in.	Primary Crater d in.	Secondary Crater l in.	Secondary Crater w in.	Secondary Crater d in.	Distance between centres in.
115	40°	32	30	9	12	8	splatter	48
116	40°	48	22	9	12	10	splatter	53
117	40°	40	30	10	11	10	1	50
118	40°	41	28	9	13	11	splatter	50
119	40°	56	36	9	12	9	5	63
120	60°	31	23	8	11	10	1	42
121	60°	36	27	7½	8	10	1	41
122	60°	36	27	8	12	11	5	42
123	60°	36	24	8½	10	11	1	40
124	60°	39	22	11	11	12	5	48
125	80°	29	16	9½	9	9	1	43
126	80°	34	9½	9	9	9	1	46
*127	80°	38	22	8½	8	8	5	49
128	80°	33	9	9	9	9	5	44
129	80°	32	20	9	12	10	1	42

*Stand-off 3D

	Charge Weight
40°	19lb 14oz
60°	16lb 2oz
80°	14lb 3oz

TABLE 11

Effect of Liner Angle on Shaped Charge performance
Shaped Charge Diameter 7in. : Attack angle 20°
Stand-off 2D

Ref. No.	Liner Angle	Primary Crater			Secondary Crater			Distance between centre in.
		l in.	w in.	d in.	l in.	w in.	d in.	
130	40	43	36	12	17	11	splatter	60
131	40	34	31	10	17	14	splatter	40
132	60	54	34	11	13	14	1	60
133	60	42	30	11	15	15	1½	56
134	80	48	30	10	14	12	splatter	48
134	80	43	28	11	11	12	splatter	52

	Charge Weight
40°	31lb 1oz
60°	25lb 1oz
80°	22lb 1oz

TABLE 12

4in Diameter Miznay-Schardin Charges. Variation of Stand-off
Normal Attack Angle
Charge Weight 3 lb 4 oz

Ref. No.	Missile Material	Stand-Off D	Crater Dimensions		
			1 in.	w in.	d in.
136	STEEL	0	16	16	$4\frac{1}{2}$
138		1	19	19	5
140		2	17	19	4
142		3	18	18	5
144		4	20	20	$4\frac{1}{2}$
137	POLYCARBONATE	0	21	21	$4\frac{1}{2}$
139		1	15	15	$3\frac{1}{2}$
141		2	16	16	4
143		3	14	14	$3\frac{1}{2}$
149		4	12	13	$3\frac{1}{2}$

TABLE 13

3 in Diameter Miznay/Schardin Charges with Steel Missiles
Variation of Angle of Attack at 1D Stand-Off
Charge Weight 1 lb 1 oz

Ref No S	Angle of Attack o	Primary Crater Dimensions			Secondary Crater Dimensions		
		l in.	w in.	d in.	l in.	w in.	d in.
12	10	9	4	¾	6	4	1
13	10	14	3½	1	5	5	1¼
11	20	9	9	1½	5	4½	1½
24	30	12	10	1½	6	3½	–
25	30	11½	10	1½	5	3	1
26	40	14	11½	2½		scrape	
27	40	10	11	1¾	5½	5½	1

TABLE 14

3 in Diameter Miznay/Schardin Charges with Steel Missiles
Variation of Angle of Attack at 2D Stand-Off
Charge Weight 1 lb 1 oz

Ref No S	Angle of Attack o	Primary Crater Dimensions			Secondary Crater Dimensions		
		l in.	w in.	d in.	l in.	w in.	d in.
14	15	10	5½	1½	5	4	1
15	15	8½	6½	1¼	4½	4½	1
22	30	12	10½	1½		scrape	
23	30	12	11½	2		scrape	
28	40	10½	13½	2	2	3½	1½
29	40	12	14½	1½	3½	4½	1
30	90	15	14	8		scrape	

TABLE 15

3in. diameter Miznay/Schardin Charges with Steel Missiles
Variation of Angle of Attack at 4D Stand-off
Charge Weight 1lb 1oz

Reference No S	Angle of Attack	Primary Crater dimensions		
		l in.	w in.	d in.
16	15	9	5	1
17	15	10	5	1½
18	20	10	7	1½
19	20	10	9	1
20	30	10½	11	1½
21	30	11½	11	1½

No secondary craters, scrape only.

TABLE 16

3 in. Diameter Miznay/Schardin Charges with Polycarbonate Missiles
Stand-off 5D
Variation of Angle of Attack
Charge Weight 1lb 1oz

Ref No. S	Angle of Attack o	Primary Crater Dimensions			Observations
		l in.	w in.	d in.	
9H	20	6	3	$\frac{3}{4}$	No secondary crater
10H	20	6	$3\frac{1}{2}$	$\frac{3}{4}$	
31E	20	6	$5\frac{1}{2}$	$1\frac{1}{4}$	
32E	20	6	5	1	
33E	20	$6\frac{1}{2}$	4	$1\frac{1}{4}$	
34E	30	7	5	$1\frac{3}{4}$	No secondary crater
35E	30	7	5	2	
36E	30	$6\frac{1}{2}$	$6\frac{1}{2}$	$1\frac{1}{2}$	
7H	30	7	7	$1\frac{1}{4}$	
8H	30	$7\frac{1}{2}$	$6\frac{1}{2}$	$1\frac{1}{4}$	
37E	40	9	$7\frac{1}{2}$	2	No secondary crater
38E	40	$9\frac{1}{2}$	8	$2\frac{1}{4}$	
39E	40	9	8	2	
40	90	10	11	$4\frac{1}{2}$	

TABLE 17

3 in. Diameter Miznay/Schardin Charges with Polycarbonate Missiles

Ref No. S	Stand-off D	Angle of Attack o	Primary Crater Dimensions			Secondary Crater Dimensions		
			l in.	w in.	d in.	l in.	w in.	d in.
1H	1	15	scrape only			5	$3\frac{1}{2}$	$\frac{3}{4}$
2H	1	20	scrape only			3	3	1
3H	2	20	4	3	$1\frac{1}{2}$	$4\frac{1}{2}$	3	$\frac{3}{4}$
4H	2	20	4	3[illegible]	$\frac{1}{2}$	4	4	1
5H	4	20	$3\frac{1}{2}$	3	$\frac{1}{2}$		NONE	
6H	4	20	5	$2\frac{1}{2}$	–		NONE	

TABLE 18

Cylindrical Charges of Plastic Explosive

Reference Number S	Charge Thickness in.	Charge Diameter in.	Charge Weight lbs	Charge Weight oz	Crater Dimensions l in.	Crater Dimensions w in.	Crater Dimensions d in.
41	1	3		7	13	15	1½
43	1	4		12	16	15	4
46	1	5	1	4	20	18	6
49	1	6	1	11	20	20	6½
52	1	7	2	8	24	24	5
44	2	4	1	8	16	21	4½
47	2½	5	2	14	21	21	7
146 W.F.	2	7½	6		30	30	5
42	3	3	1	4	15	14	2¾
50	3	6	5	1	24	24	11
53	3½	7	8	1	28	28	10
45	4	4	2	15	17	18	6
48	5	5	5	13	24	20	9
51	6	6	9	12	24	24	12

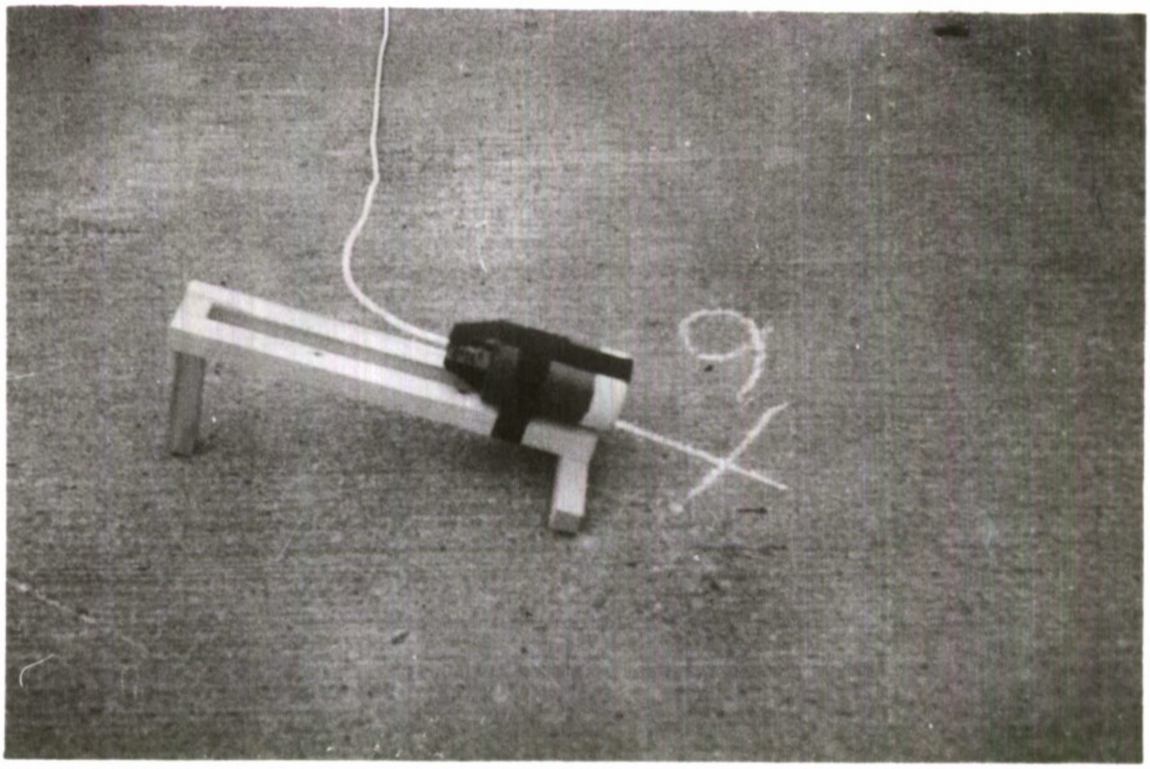


FIG. 1 (a) EXPERIMENTAL SHAPED CHARGE PREPARED FOR FIRING

FIG. 1 (b) TYPICAL SHAPED CHARGE SIGNATURE AT WEST FREUGH

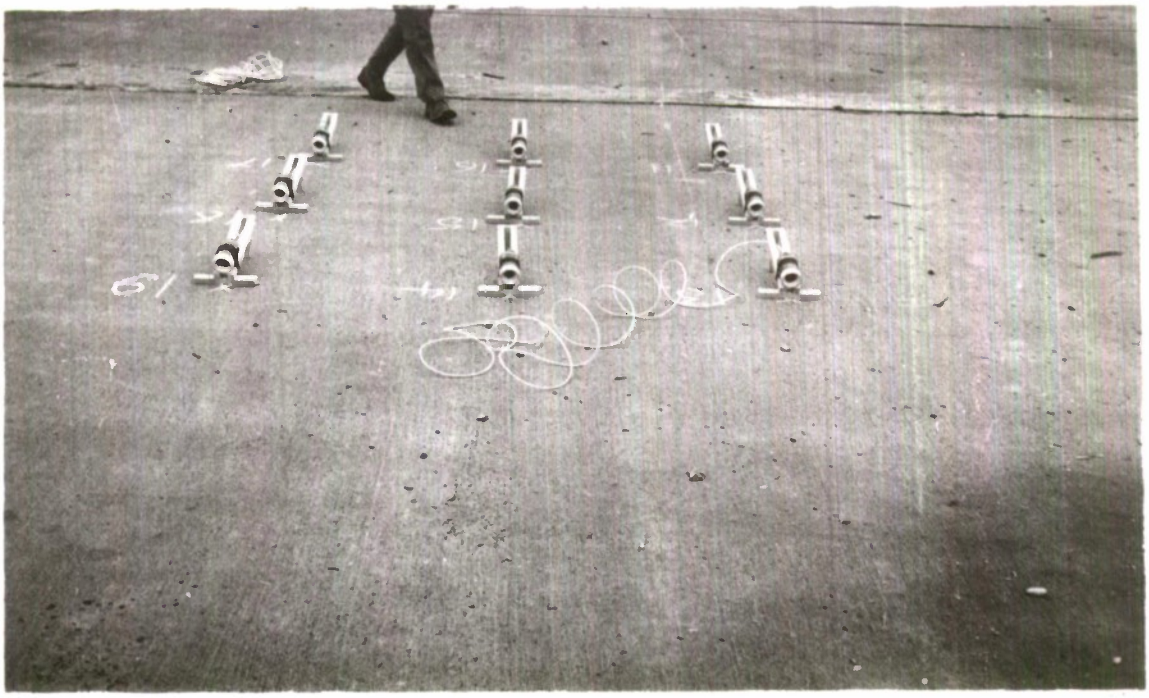


FIG. 2(a) SHAPED CHARGES SET FOR FIRING AT WEST FREUGH

FIG. 2(b) NINE BL 755 SHAPED CHARGES AT 3 ft CENTRES FIRED SIMULTANEOUSLY AT WEST FREUGH

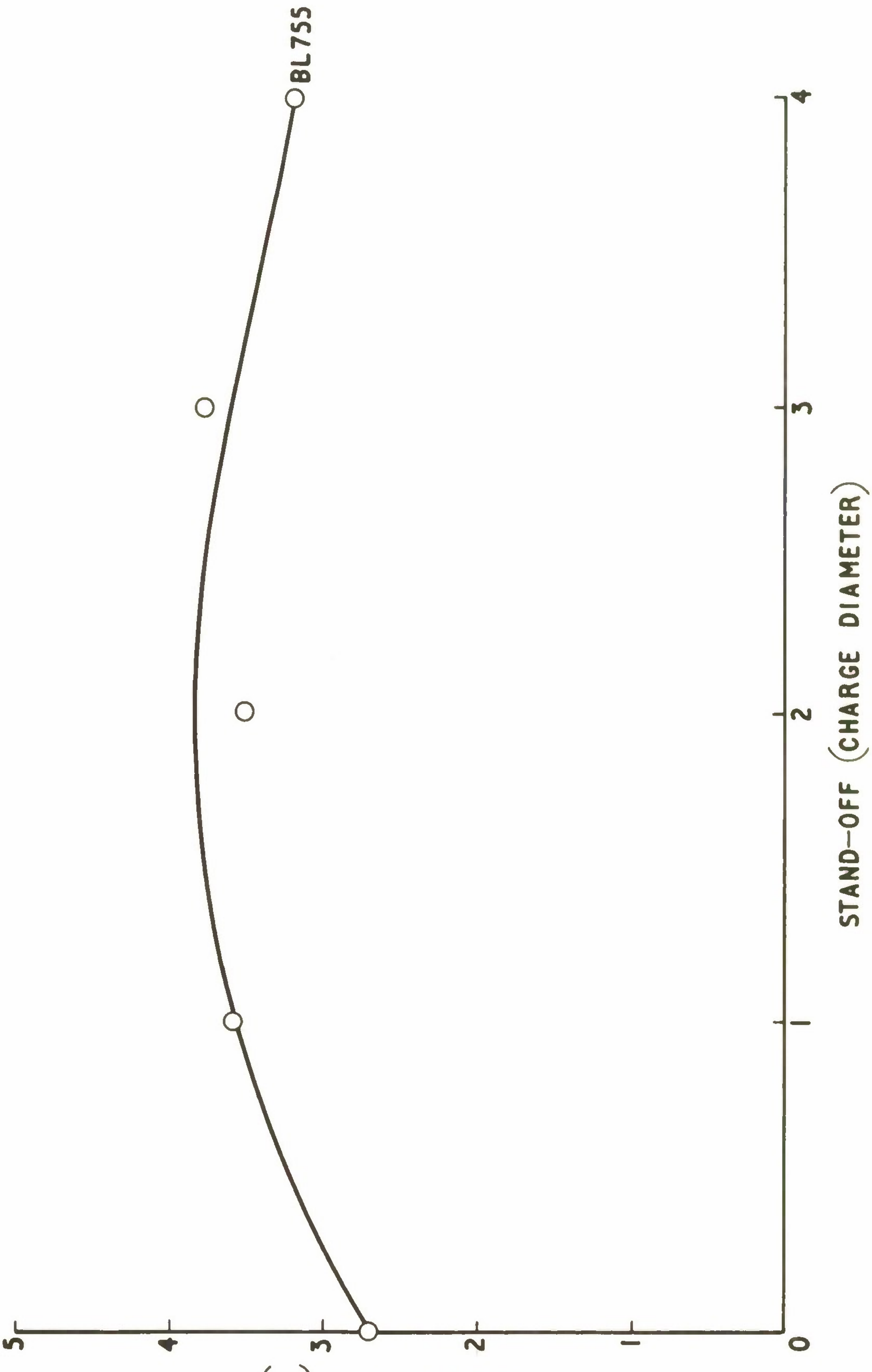


FIG. 3 BL 755 CRATER DEPTH VARIATION WITH STAND-OFF

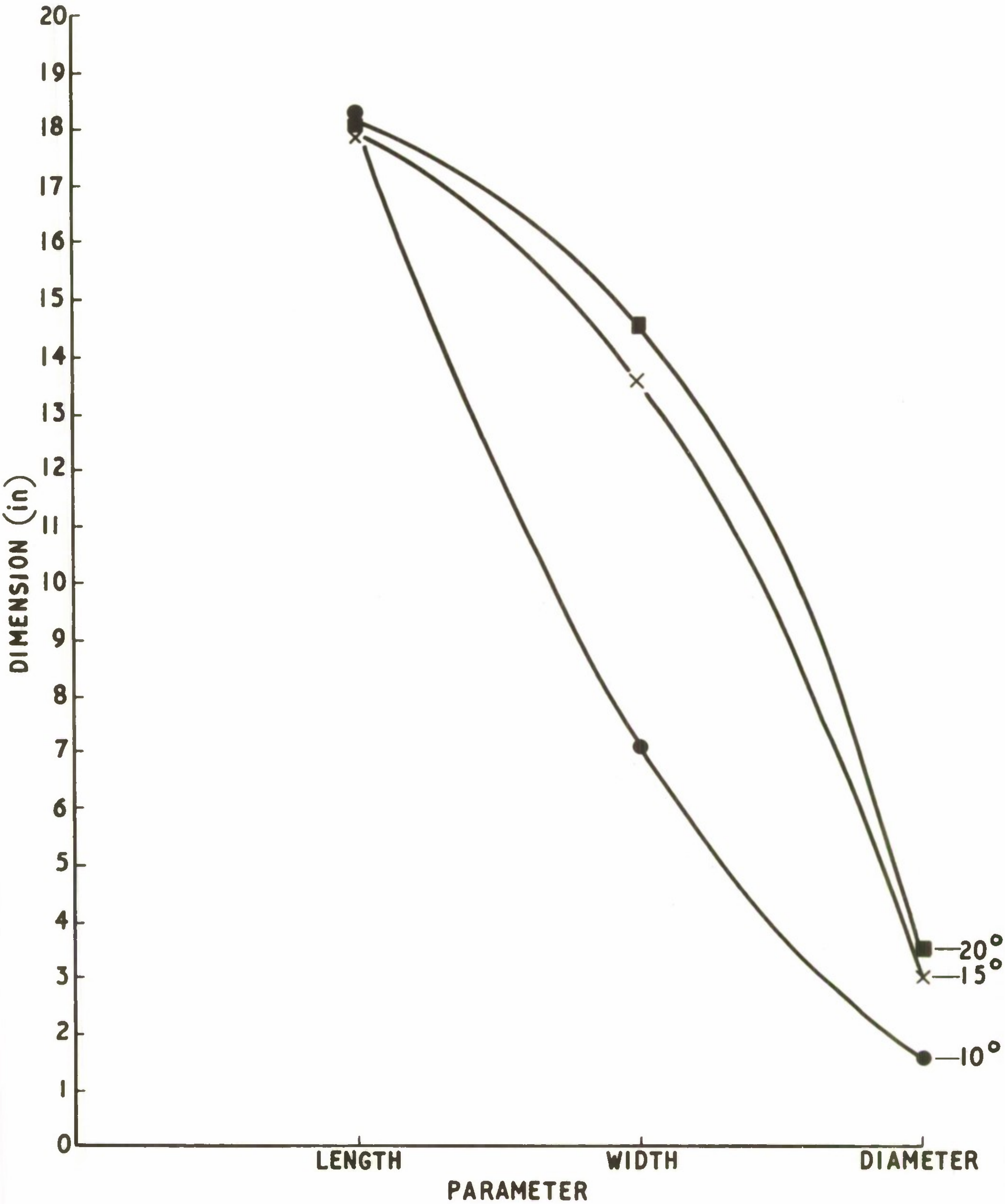


FIG. 4 BL 755 CRATER PROFILES AT THREE ANGLES OF ATTACK

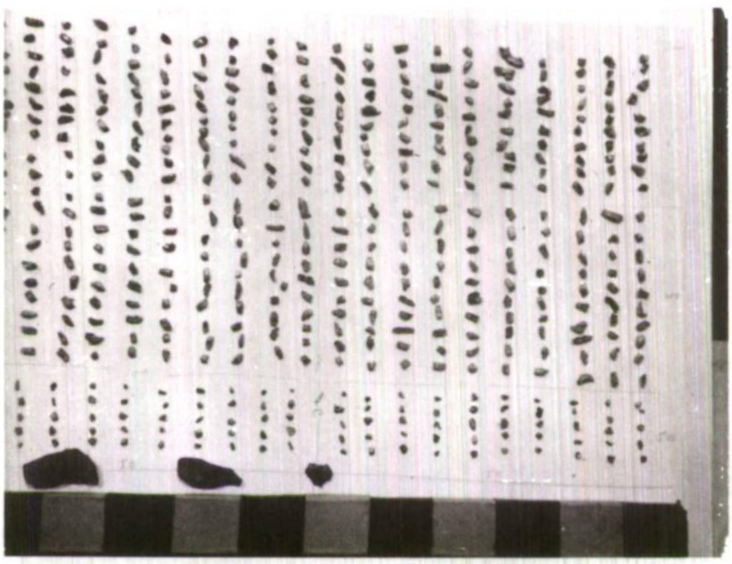


FIG. 5 500 FRAGMENTS RECOVERED FROM BL 755 WARHEAD

FIG. 6

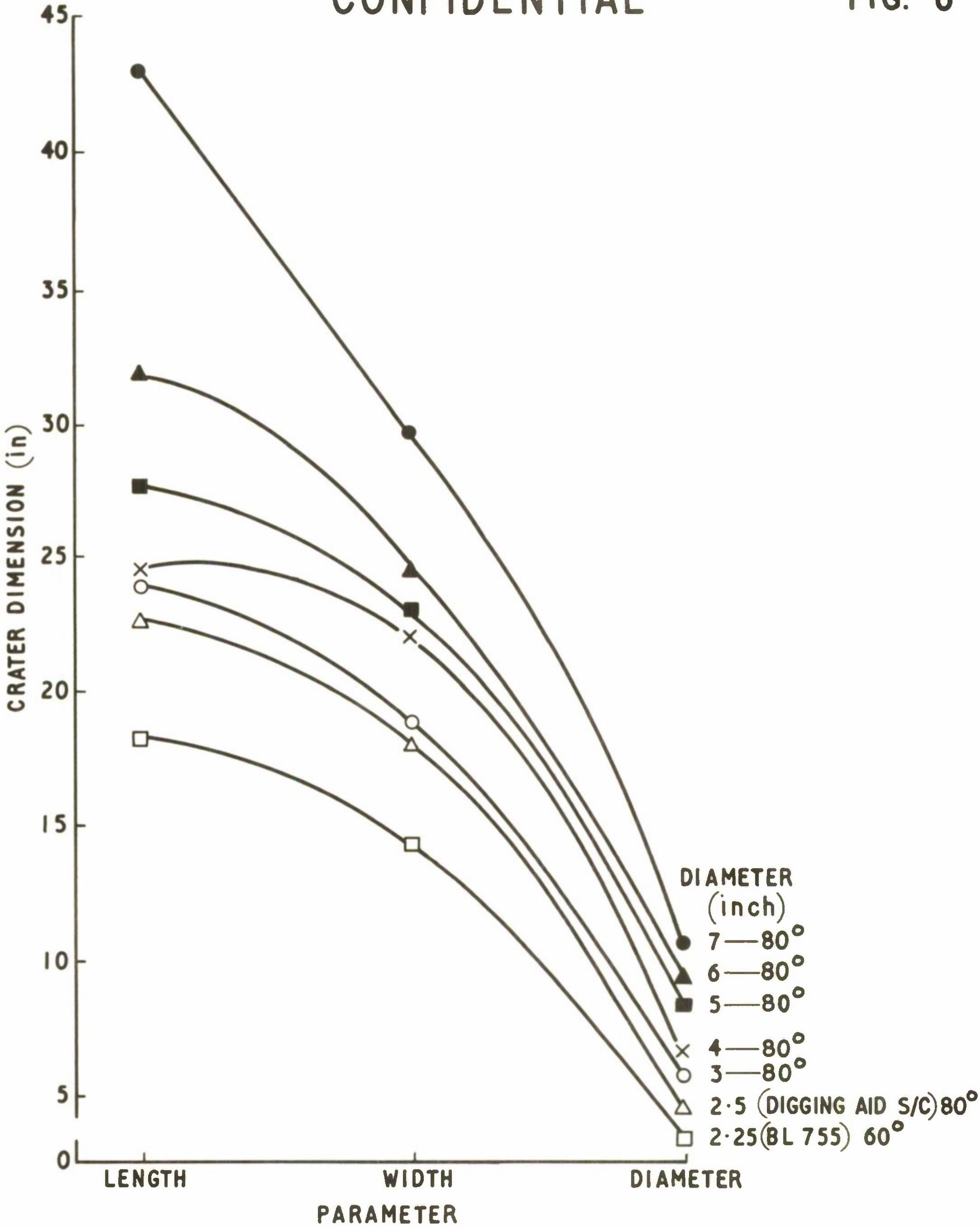
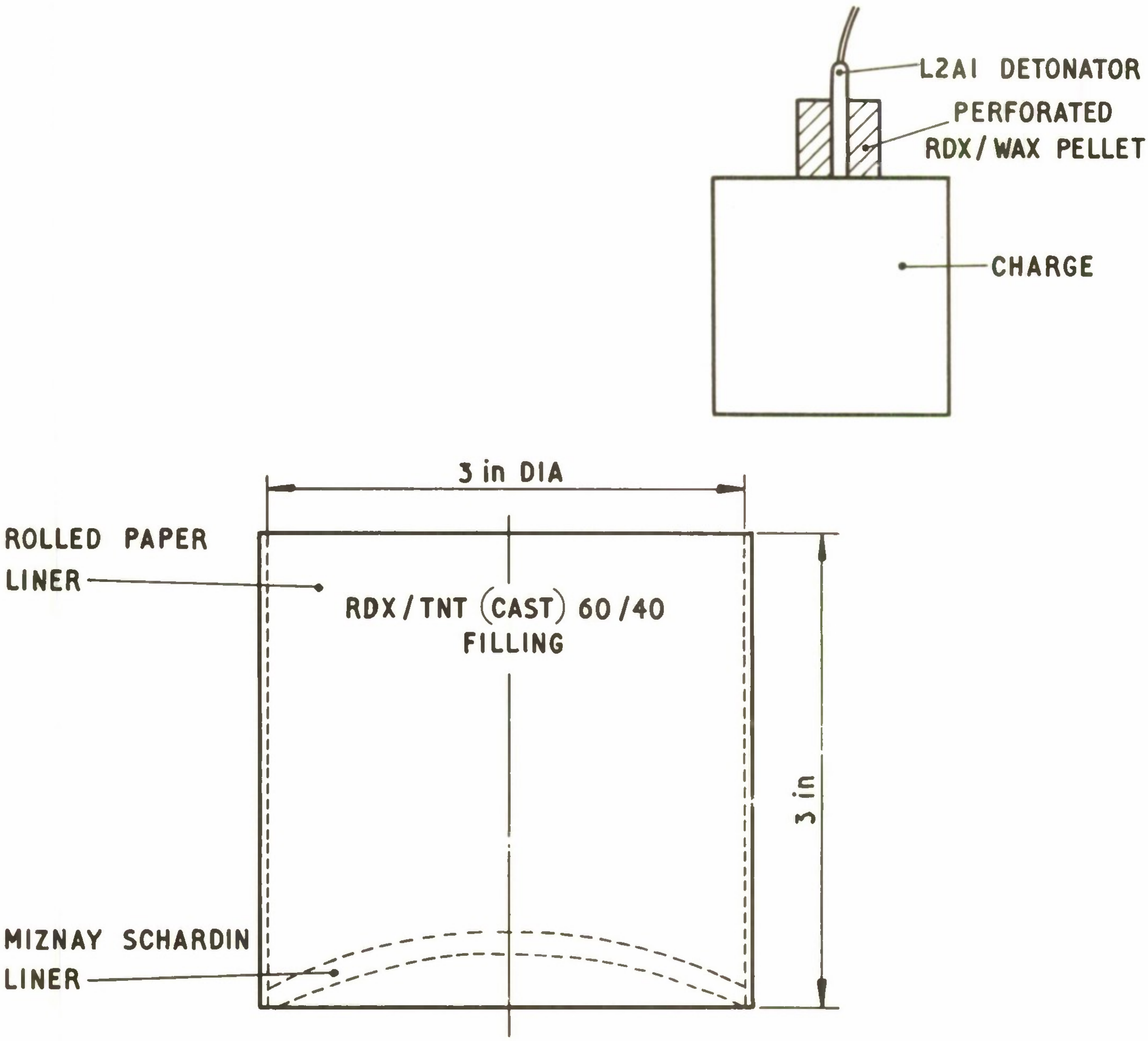


FIG. 6 PERFORMANCE OF SHAPED CHARGES AT 2D STAND-OFF AND 20° ANGLE OF ATTACK

FIG. 7 (a) WEST FREUGH CRATER PRODUCED BY 5 in DIAMETER SHAPED CHARGE

FIG. 7 (b) WEST FREUGH CRATER PRODUCED BY 7 in DIAMETER SHAPED CHARGE



LINERS

	REF.	CHORD DIAMETER (inch)	SPHERICAL RADIUS (inch)	THICKNESS (inch)
POLYCARBONATE	E	3	4	0·25
	H	3	3	0·25
STEEL		3	3·3	0·125

FIG. 8 SKETCH OF EXPERIMENTAL MIZNAY SCHARDIN CHARGE

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623.452.31:
623.562.4:
629.139.1:
623.451.082.6

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20 pp. 8 figs. 18 tabs. 2 refs.

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